INITIAL ASSESSMENT OF THE ASSET MANAGEMENT PROCESS OF A LARGE INDUSTRIAL PLANT INCLUDING PROBABILISTIC RELIABILITY ANALYSIS

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ABSTRACT

Engro Fertilizer and Siemens PTI jointly completed a study on the supply reliability situation and on the asset management process in Engro Fertilizer's Daharki (Pakistan) plant. This project complemented earlier projects on, e.g., the overall design and the dynamic performance of the captive generation units in this industrial power supply system. Probabilistic reliability calculations validated that the reliability level throughout the plant is adequate and rather constant. A few individual exceptions are well-known to the operators and covered by explicit processes and measures. Also the asset management process was reviewed from the perspective of the plant's overall reliability performance, and the development plans existing with Engro Fertilizer were confirmed. For certain individual assets or groups of assets, the investigations indicated the need for faster implementation in order to maintain the required risk levels for the plant's operation.

INTRODUCTION

Even though the term "asset management" is frequently used today, there exists no detailed and commonly accepted definition of asset management as it is applied in the electricity sector. The different general frameworks in separate electricity markets or with different industrial customers, and the different situation of each individual network operator with respect to both technical and organizational aspects motivate different specifications of asset management.

In general, asset management methods consider the economical and technical performance criteria of the electricity supply system. This consideration typically covers the whole technical lifecycle.

The high complexity of the correlations between network cost and power quality, especially concerning effects in the long term, is one of the main difficulties in asset management. As these correlations are of predominant importance, information as detailed as possible for the support of asset management decisions is required – even though the data processing techniques as well as the input data might not be easily available in a sufficiently detailed structure and appropriate quality.

In most cases, gathering and evaluating the economic aspects is less problematic than for the technical aspects. But the application of up-to-date network planning methods, like e.g. probabilistic reliability calculation, allows an objective quantification of quality aspects.

The Reliability Centered Asset Management (RCAM®) process [1] was developed as a comprehensive approach for the description and analysis of strategies for preventive maintenance and preventive replacement in electrical power supply networks. The RCAM process focuses on the evaluation of the system's technical and economical performance by considering relevant events and aspects of the separate network components and their impact on system performance (Figure 1). With respect to technical performance of the system, especially the supply reliability delivered by the system to end-customers is relevant in asset management considerations. Supply reliability is significantly influenced by network structure and component condition – which are both, especially component condition, influenced by decisions on preventive maintenance and preventive replacement.

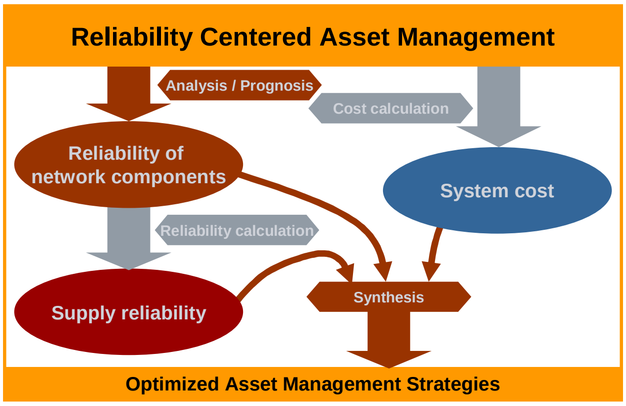

Figure 1: Concept of the RCAM process

While cost calculation and probabilistic reliability calculation are well established methods, the challenge addressed by the RCAM process is to model the quantitative effect of changes in the asset management strategies on the reliability performance of network components, and to combine all the available information and intermediate results into the synthesis of improved strategy parameters for preventive maintenance and preventive replacement.

ANALYSIS OF CONSIDERED SYSTEM

Engro Corporation Ltd. operates an ammonia and urea production facility in Daharki, Pakistan. The production facilities comprise an existing Base Plant and the recently added enVen 1.3 complex. The plant comprises significant captive generation capacity from gas turbines, so that the complete plant can also run in island operation. Dynamic stability and the islanding process to decouple from the public power network have been subject of previous studies, and the system's capabilities have been successfully demonstrated in practice. The overall single line diagram is given in Figure 2.

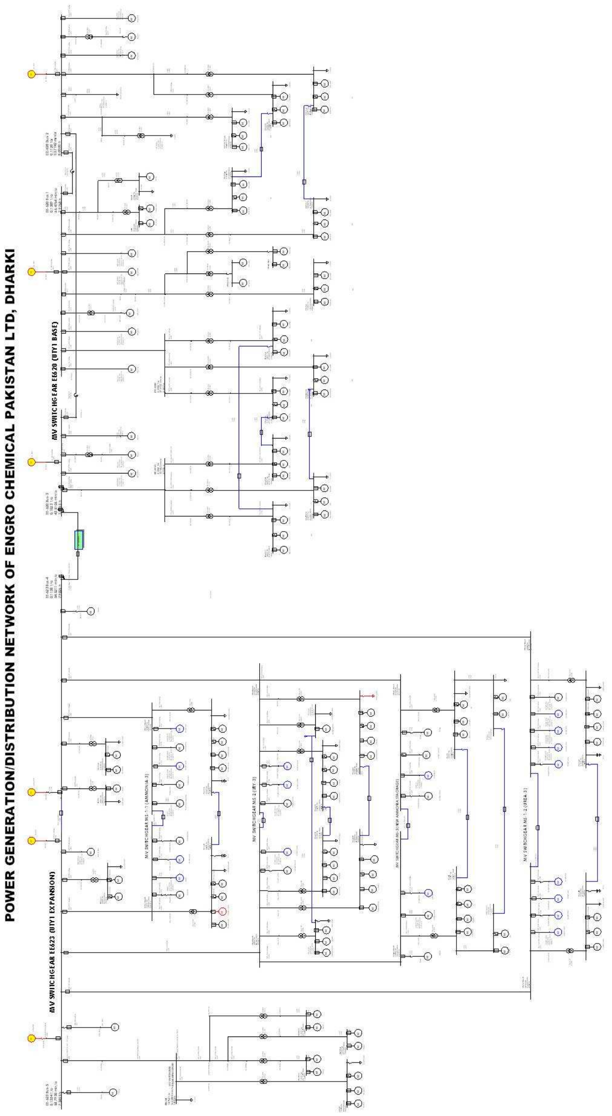

Figure 2: Model of investigated system

A probabilistic reliability calculation [2] was performed for the system model in a defined peak load scenario using the network calculation tool PSS®SINCAL [3]. Probabilistic reliability calculation has successfully established as a standard method for detailed and quantitative reliability analyses in numerous studies and practical applications. It is characterized by three main aspects:

- Stochastic generation of contingency states to consider the impact of equipment outages on system performance
- Network state analysis to assess the impact of outages on the supply situation of customers
- Modeling of supply restoration process to determine the duration of supply interruptions

The reliability calculation considered the failure models Independent Single Failure (also the overlapping of multiple, independent failures) and Malfunction of Protection Device. Data on the outage performance of network equipment was determined on the basis of the actual outage performance as statistically recorded in Engro, and considering additional details from the outage statistic of public power supply systems in Germany [4].

Typical reliability indices delivered by probabilistic reliability calculations are Frequency of Supply Interruption and Non-Availability (or Probability of Supply Interruption). Figures 3 and 4 show the contour plots of Frequency of Supply Interruption and of Non-Availability respectively, calculated for the MV and LV parts of the network. The absolute range is from about 0.1 1/a to 2 1/a for the Frequency of Supply Interruptions for different buses in the plant's system, and from about 20 min/a to 200 min/a for Non-Availability – with the high values appearing on a small number of buses only, as indicated in the plots.

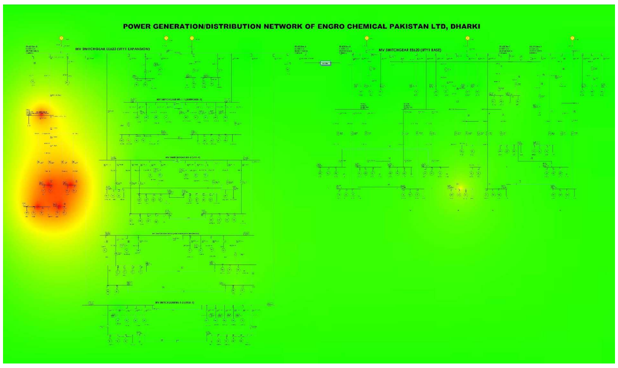

Figure 3: Contour plot of Frequency of Supply Interruption

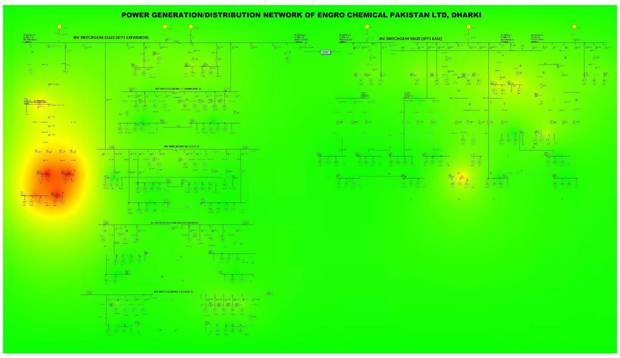

Figure 4: Contour plot of Non-Availability

Results show that the overall reliability level of the plant is good. Higher values for the reliability indices were obtained for certain non-production areas as well as for parts of the Base Plant – areas supplied by radial network structures.

Apart from the reliability results for individual busbars, or for the complete system, the identification of most relevant components contributing to the observed un-reliability (weak point analysis) is important. For the considered

network, these are all overhead lines which are part of T-offs to transformers. The individual contributions were further used in the importance assessment process.
The following measures applied to the network structure would improve the overall supply reliability performance:

- Transforming radial feeders into open ring structures
- Eliminating T-offs
- Replacement of overhead lines with underground cables
- Adding redundancies to the generation system

ADAPTED RCAM PROCESS

Typically, not all the separate modules of the RCAM process are considered in a specific project. Here, an initial assessment of the asset management process with respect to the plant's electricity supply system was executed. The initial assessment serves to identify further actions and measures that may be recommended in order to improve the plant's technical and/or economical performance. The initial assessment considers high-level aspects on system level, rather than details on component level. Details on component level would be addressed in subsequent steps as identified and recommended in this initial assessment. Figure 5 shows the adapted RCAM process for the project.

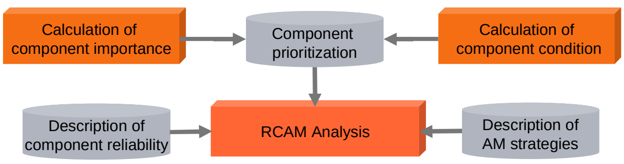

Figure 5: Overview of adapted RCAM process

The core elements are:

- Component prioritization based on suitable definitions and evaluation of component importance and component condition indices
- RCAM analysis evaluating and assessing the expected future supply reliability performance of the system

In the course of a workshop at Engro's site, the relevant asset classes were defined (19 in total) as well as the related condition assessment attributes and importance assessment attributes. For selected assets a condition assessment has been carried out on site in order to exemplarily demonstrate the procedure and to collect condition data.

ASSET ASSESSMENT AND PRIORITIZATION

The component importance assessment scheme to be applied in the RCAM process should focus mainly on the influence of individual components on the overall system reliability performance. Table 1 lists the selected attributes, attribute weighting and data sources for this project.

The component condition assessment scheme to be applied in the RCAM process should focus mainly on the physical condition of the network components with respect to effects on the component's outage performance. The agreed component condition assessment scheme is given in Table 2. The subordinated surveillance condition assessment schemes consider different attributes depending on the asset class.

Table 1: Component importance assessment scheme

Importance Attribute		Quality		Weight factor	Data Source
Identifier	Description	Description	Value		
Frequency of s.i.	F_I per component	Individual results	0 - 15	15	Calculation
Unavailability	Unavailability Q_I per component	Individual results	0 - 15	15	Calculation
ProcessCrit	Criticality of load structure Production loss costs	supply of less important load	10	50	Process structure
		supply of normal load	20		
		supply of important load	30		
		supply of highly critical load	40		
		loss of large parts of plant	50		
		loss of entire plant supply	60		
CostCrit	Replacement/Repair of comp.	Internal Repair	5	20	Operation
		External Repair	10		
		Replacement	15		
		Repair+Replacement	20		

Table 2: Component condition assessment scheme

Condition Attribute		Quality		Weight factor	Data Source
Description	Detail	Description	Value		
Age (related to std. service life)		0 - 5 %	10	20	Register
		5 - 50 %	5		
		50 - 75 %	10		
		75 - 90 %	15		
		90 - 100 %	20		
		> 100 %	25		
Serviceability	Spare parts availability	Very Good	0	20	Expert assessment (per component class)
		Fair	5		
		Poor	15		
	Availability of skilled staff	Very Good	0		
		Fair	2		
		Poor	5		
Ambient Conditions	Indoor/Outdoor	Indoor	0	10	Network topography, local conditions
		Outdoor	5		
	Exposure to stresses (atmospheric, ammonical	Low	0		
		Normal	1		
		High	3		
		Very High	5		
Peak Loading (related to th. capacity)		0-70 %	0	10	Calculation
		70 - 85 %	3		
		85 - 95 %	5		
		> 95 %	10		
Operational safety		Good	0	5	Expert assessment
		Poor	5		
Operational experience		Very Good	0	5	Expert assessment (per component class or individual)
		Fair	3		
		Poor	5		
Surveillance Condition assessment			0 - 30	30	Expert assessment

From the collected and calculated data, the condition and importance indices were calculated for each component. A high-level overview of the prioritization results for all assets is given in the asset prioritization diagram in Figure 6.

The following recommendations were derived:

- For components showing high values in the asset condition assessment (e.g. values above 0.6; i.e. a bad asset condition), refurbishment or replacement options should be investigated. Mitigating high condition indices will directly reduce the overall risk of interruptions to power supply and to the production processes, and also reduce the risk of damages to persons and equipment.
- For components showing high values in the asset importance assessment (e.g. values above 0.85; i.e. very

important assets), options to intensify inspections and/or scheduled maintenance activities, and/or to advance preventive replacements (i.e. reducing the scheduled service life) should be investigated. Such investigations should also consider the respective condition assessment of the assets.

- For components showing low values in the asset importance assessment (e.g. values below 0.4; i.e. not very important assets), and showing low to medium values in the asset condition assessment (e.g. values below 0.4; i.e. good to fair asset condition), options to reduce maintenance efforts and/or to extend the scheduled service life (i.e. to postpone preventive replacements) may be investigated. The efforts saved on such components may be spent on more important assets, and/or on assets in worse condition – so that the spent efforts will have a higher lever on overall system reliability.

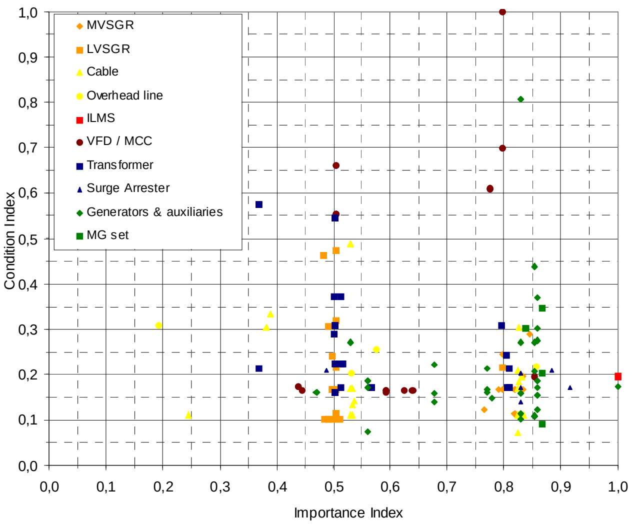

Figure 6: Asset prioritization – all assets

ASSESSMENT OF AM PROCESS

When investigating the present asset management process, the following main findings and recommendations were derived:

- The developed assessment schemes should be implemented into the asset management process and applied for a time period of at least 3-5 years (e. g. in the course of regular inspections) in order to build a trustworthy database and to evaluate the development over time.
- While the detailed asset management processes addressing the component level are on a very high standard already, especially the electronic collection, processing and storage of asset data covering the system level would lead to much better usability of the valuable data and results. Appropriate recommendations were given in the study report.
- The comprehensive scope and the high frequency of inspections, compared to other industrial installations worldwide, is highly appreciated and forms a solid basis for the asset management process. In the future, inspections and maintenance activities should be clustered per asset class focusing on feasible options to either reduce or to increase such activities per asset class, also taking into consideration the overall technical and economical framework. This clustering will then describe possible alternatives for changes in the plant's asset management plans.

CONCLUSION

The initial assessment of the asset management process defined and implemented at the plant underlines the high standard of the process and the involved staff. In total, the electrical power supply equipment is managed and maintained in a highly appropriate way. Adequate predictive and preventive maintenance regimes through adequately trained manpower are being followed. As a result, the equipment failure analysis shows good numbers against availability of all major equipment.
Vulnerable areas identified through this study are being worked upon by Engro. A detailed replacement plan has been developed for old transformers pruned to failure due to their aging. Additionally, investment is planned for interconnecting the two off-sites through a MV line. Preventive maintenance and testing plans are also being modified to further strengthen the maintenance regime for critical equipment.

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